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Multi Objective Optimization in Turning of AISI 4340 Alloy Steel using Response Surface Methodology

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***Abstract* - Now a days, main challenges to metal cutting industries are productivity and quality of product or component. The machining parameter of any machining process highly affects the quality of product. Surface roughness is a key indicator to quality of product or component in turning process. In this paper, the effect of machining parameter on surface roughness and roundness in turning of AISI 4340 steel is investigated with Response Surface Methodology. This work analyse the effect of cutting parameters on the roundness of cylindrical parts for AISI 4330 steel in the turning operation. An experimental design by Response Surface Methodology done in this work, the control variables were: cutting speed, feed rate and depth of cutting. Metal cutting experiments and statistical tests demonstrate that the Cutting Speed significantly affects the roundness of cylindrical part. Also, the relations between the Cutting Speed –Feed Rate and Cutting Speed –Depth of Cutting affect the roundness of work piece too. Additionally, the experimental design is optimized to minimize the effect of roundness. Finally, further research directions are presented.**

I. INTRODUCTION

To study the surface integrity of AISI 4340 steel using Response Surface Methodology.The purpose of this work is to analyse the effect of cutting parameters on the Straightness, Hardness, material removal rate and surface roughness of cylindrical rod (AISI 4340 steel) in the turning operation. The main objective of the work is to improve the surface integrity of the machined rod. Turning Operation is performed on a cylindrical rod of dia. 50 mm, length 300mm of AISI 4340 Steel.

Optimization of output parameters like

- Roundness
- Material Removal Rate
- Surface Roughness
- Hardness which are influenced by the input parameters.

The present modern industry of machining processes demands products with close specifications and low costs, so we are studying the effects of cutting parameters such as cutting speed, feed rate and depth of cut among the wide set of parameters.The effect of the cutting parameters on the Roundness, Straightness, MRR, Surface and Tool tip temperature of the turned part has not been sufficiently studied. It is difficult to achieve the greatest performance of a machine because there are so many adjustable machining parameters. In order to minimize these machining problems, there is a need to find optimum cutting conditions for lathe turning

II. LITERATURE REVIEW

[1] Das et al have evaluated the machinability of AISI 4340 alloy steel using a different levels of cutting parameters in dry cutting surroundings. Based on the study they have concluded that the Coated cermets provides better result compared to uncoated carbides inserts(Low cutting force, less flank wear and low work piece surface temperature) due to coating of cermets inserts.

[2] P.K.Sood et al have performed the experiments on AISI 4340 alloy steel using uncoated tungsten carbide inserts under the varying condition of process parameters (e.g., Cutting speed, feed rate, and different cooling conditions).Based on the experiments & optimization performed, authors have concluded that cooling condition is the most significant parameters followed by feed & cutting speed.

[3] Singh et al have proposed that small change in nose radius will affect the surface roughness by large extent in dry turning of aluminium 6061. They have also concluded that the average surface roughness value will increases with increase in feed rate and cutting speed within a specified range. Also the depth of cut will adversely affect surface finish but in a small extent.

[4] M.K. Gupta et al have discussed effect of cooling method and cutting parameters (cutting speed and feed rate) on cutting force, tool wear and surface roughness. ANOVA and Grey relational analysis are executes to study the effects

percentage contribution and optimum setting for given process parameter. Authors have concluded that the cryogenic cooling is an effective alternative to dry and wet cooling in turning of AISI 4340 steel with coated carbide insert.

[5] M. Adinarayana et alhave performed multi objective optimization of turning parameterfor turning on AISI 4340 allow steel. Authors have concluded that the cutting speed hashighest influence followed by depth of cut on surface roughness. Material removal rate and power consumption have increasing behaviour with increase in speed, feed and depth of cut. Material removal rate has highest influence of cutting speed and depth of cut has highest influence on power consumption.

Element	Composition % min	Composition % max
Carbon	0.36	0.44
Silicon	0.10	0.35
Manganese	0.55	0.90
Nickel	1.55	2.00
Chromium	0.65	0.95
Molybdenum	0.20	0.35
Phosphorous	0.0	0.04
Sulphur	0.0	0.04

Material properties	AISI 4340 steel
Physical density	7.84 g/cm^3
Mechanical hardness, Rockwell *B*	99 HRB
Tensile strength, ultimate	1000 Mpa
Tensile strength, yield	310 Mpa
Elongation of break	25%
Modulus of elasticity	200 Gpa

III. MATERIAL - AISI 4340 STEEL

4340 is a steel having 1.8% of nickel - chromium – molybdenum metals, high hardenability, high tensile steel. Generally supplied hardened and tempered in the tensile range of 930 - 1080 Mpa.Characterized by high strength and toughness in relatively large sections.Pre hardened and tempered metal AISI 4340 can be further surface hardened by flame or induction hardening and also by nitriding.

Table no: 3.1

Table no: 3.2

IV. RESPONSE SURFACE METHODOLOGY

Response surface methodology (RSM) mathematical and statistical techniques for empirical model building. By design of experimentations, the objective is to enhance the response (output variable) which is influenced by several independent variables (input variables). An experiment is a series of tests, called runs, in which changes are made in the input variables in order to identify the reasons for changes in the output response. An important aspect of RSM is the design of experiments, usually abbreviated as DoE. These approaches were initially developed for the model suitable of physical experiments, but can also be functionally applied to numerical experiments. The objective is the selection of the points where the response should be evaluated.

V. ROUNDNESS

Roundness is the study of the shape of an object approaches that of a mathematically perfect circle. Roundness applies in two dimensions, such as the cross sectional circles along a cylindrical object such as a shaft or a cylindrical roller for a bearing. Roundness of the machined rod should be low for optimum condition.

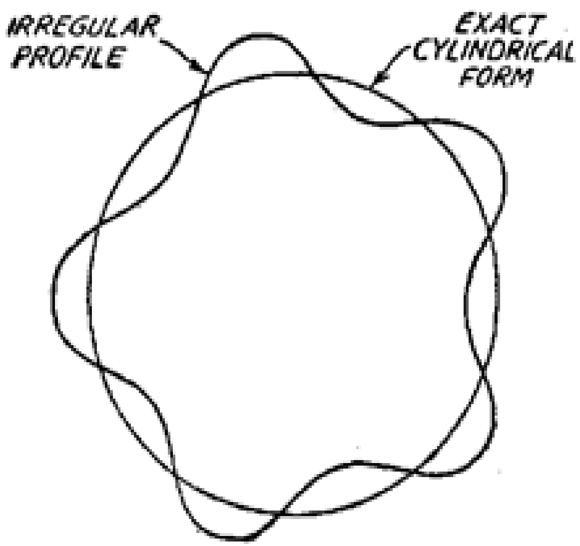

Fig no: 5.1

VI. MATERIAL REMOVAL RATE

The material removal rate, define as the ratio of the volume of material removed to the machining time. Another way to define MRR is to imagine an "instantaneous" material removal rate as the rate at which the cross-section area of material being removed moves through the work piece. The MRR should be high for obtaining optimum surface conditions.

VII. SURFACE ROUGHNESS

Surface roughness is a factor of surface quality. It is computed by the deviations in the direction of the normal vector of a real surface from its model form. If these strangenessare large, the surface is rough, if they are small, the surface is smooth. In surface metrology, roughness is generallymeasured to high frequency, short wavelength component of a surface. However, in practice it is often essential to know both the amplitude and frequency to safeguard that a surface is fit for a perseverance. Roughness plays an important role in responsible how a real object will relate with its environment. In tribology, rough surfaces regularly wear more quickly and have higher friction coefficients than smooth surfaces. Roughness is often predicts the demonstration of a mechanical component. Since indiscretions on the surface may form nucleation spots for snaps or corrosion. On the other hand, roughness may promote adhesion.

Sl. no.	Parameters	Level 1	Level 2	Level 3
1	Cutting speed (*v*), m/min	220	250	280
2	Feed (*f*), mm/rev	0.1	0.2	0.3
3	Depth of cut (*d*), mm	0.3	0.6	0.9

Table no: 7.1

VIII. MATERIAL HARDNESS

Hardness is aamount of how sturdy solid matter is to numerous kinds of permanent shape change when a compressive force is applied. Some materials are harder than other. Macroscopic hardness is generally categorized by strong intermolecular bonds, but the performance of solid materials under force is complex; therefore, there are different measurements of hardness: scratch hardness, depression hardness, and rebound hardness.Hardness is dependent on the parameters like ductility, elastic stiffness, plasticity, strain, strength, toughness, viscoelasticity, and viscosity.Mutualsamples of hard matter are ceramics, concrete, certain metals, and superhard materials, which can be related with soft material.

IX. BACKGROUND

In any typical metal-cutting process, the principal factors that define quality are dimensional accuracy and surface finish (Watanabe and Iwai 1983). Several constraints limit the improvement of part dimensional accuracy and surface finish (Dickinson 1967): Prediction of surface roughness is always considered important in the manufacturing field. The purpose of this work was to analyse the effect of cutting parameters on the roundness, material removal rate, surface roughness and Hardness of cylindrical parts for AISI 4340 steel in the turning operation. An experimental Design by Response Surface Methodology was done in this work, the control variables were: cutting speed, feed rate and depth of cutting. Metal cutting experiments and statistical tests verified that the Cutting Speed expressively affects the roundness of cylindrical part. Also, the relations cutting speed –Feed Rate and Cutting Speed –Depth of Cutting affect the roundness of work piece too. Additionally, the experimental design was optimized by minimized the roundness; finally, further research directions are presented.Actually, the modern industry of machining processes stresses products with close specifications and low costs, this market condition is aggressive to researchers to study the effects of cutting parameters such as

- cutting speed
- feed rate
- depth of cut
- tool geometry, among the wide set of factors.

X. METHODOLOGY

This experimental work was carried out on specimens of AISI 4340 steel using a lathe machine. Turning Operation was performed on a cylindrical rod of dia. 50 mm, length 300mm of AISI 4340 Steel.In order to analyse the effect of cutting parameters on the output parameters, a full experimental design with 20 trials was performed. These experiments were carried out with different combinations; each treatment was run randomly. To measure the roundness and straightness kenchy dial gauge was used, the surface and the tool tip temperature were measured usingMetravi DTM-100. The Levels of The Variables Used in The Experiment:

Table no: 10.1

INPUT PARAMETERS	LOW	MEDIUM	HIGH
CUTTING SPEED mm	135	280	427
FEED RATE (mm/sec)	0.3	0.53	0.83
DEPTH OF CUT (mm)	0.6	0.8	1

XI. OBJECTIVE

From the influencing parameters that we have taken into consideration cutting speed, feed, depth of cut. We have to determine the most influencing parameter. An increase in cutting speed reduces the surface roughness and increase in feed rate increases the surface roughness. Feed rate influences the most in surface roughness compared to the other parameters. To generate a optimum surface integrity which is crucial for achieving the needs of the project. To provide best surface quality in lower machining time and low cost. The experiment will be done using lathe machine by the process of turning.

XII. CONCLUSION

In this work, the conclusions and recommendations obtained are the follows:The cutting speed significantly affects the roundness of the material.The interfacebetween cutting speed- feed rate significantly affects the roundness of cylindrical bar. The contactbetween cutting speed- Depth of Cut significantly affects the roundness of cylindrical bar. For further works, it is recommended to analyse the effect of others parameters on the roundness of cylindrical bar with others materials of the workpiece.

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